Dynamically-Configurable, Dynamically Steerable Foveal Infrared Focal Plane Array

A White Paper

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¶ 1 Based upon technology developments produced over the last decade, it is now possible to design an infrared focal plane array (FPA) that incorporates a dynamic, user-defined spatial distribution of pixels with programmable sensitivities. Although virtually any spatial configuration (i.e., size and location) of pixels could be defined, an important first system to be realized could be that of the vertebrate fovea.

¶ 2 A "foveal FPA" as discussed here would have the properties of higher spatial frequency of pixel channels near the "center of attention" (COA), with a radially-symmetric spatial frequency diminishing radially out from the COA. The device as described permits the user to define any desired spatial distribution of pixels, and may change this distribution at the frame rate, if desired. In this way, the COA may be directed to move within the total field of view of the FPA in order to track objects of interest with high angular precision, without sacrificing the ability to detect other targets which may enter into the sensor's periphery.

¶ 3 This design would also incorporate the ability to "program" the sensitivity of any given pixel, so as to produce peripheral pixels with higher radiometric sensitivity. Also included would be the capability to read out only desired pixels within the foveal (or user-defined) spatial distribution, such that frame rates could be maintained efficiently high.

¶ 4 To be demonstrated throughout the remainder of this paper, every operational advantage required of a tactical imaging sensor would be afforded through the use of this new class of imaging device:

¶ 5

- User-defined spatial distribution of pixels permits high accuracy "on target", while retaining detection over the entire FOV. Each pixel gets programmed into a specific "superpixel" state, and it will "know" how to share its charge with neighbors such that a resulting superpixel distribution is produced.
- Also set during a pixel programming step, user-defined pixel sensitivity permits peripheral pixels in a foveal sensor to be operated in a mode such that, even though larger in angular size, they would retain the ability to detect small targets by boosting sensitivity.
- High frame rates would be possible by programming individual pixels with a "readout" attribute. Since the controlling processor determines the shape of the spatial distribution of pixels, it would "know" which pixel channels would need to be read out. This will minimize the total number of pixel values required to be delivered off-FPA, thus maximizing effective frame rate.

¶ 6 This general methodology could be applied to the use of multispectral detector arrays as well. These capabilities are now possible through the use of "READIN" commands to the FPA, used to program the characteristics of individual pixels in the array. Figure 1 demonstrates the concept of "FPA READIN Programmability", resulting in a user-defined effective distribution of pixels, each having specific operational properties. Also indicated in the figure that the integration time state and the readout state for each pixel may be individually programmed through the use of the readin command.

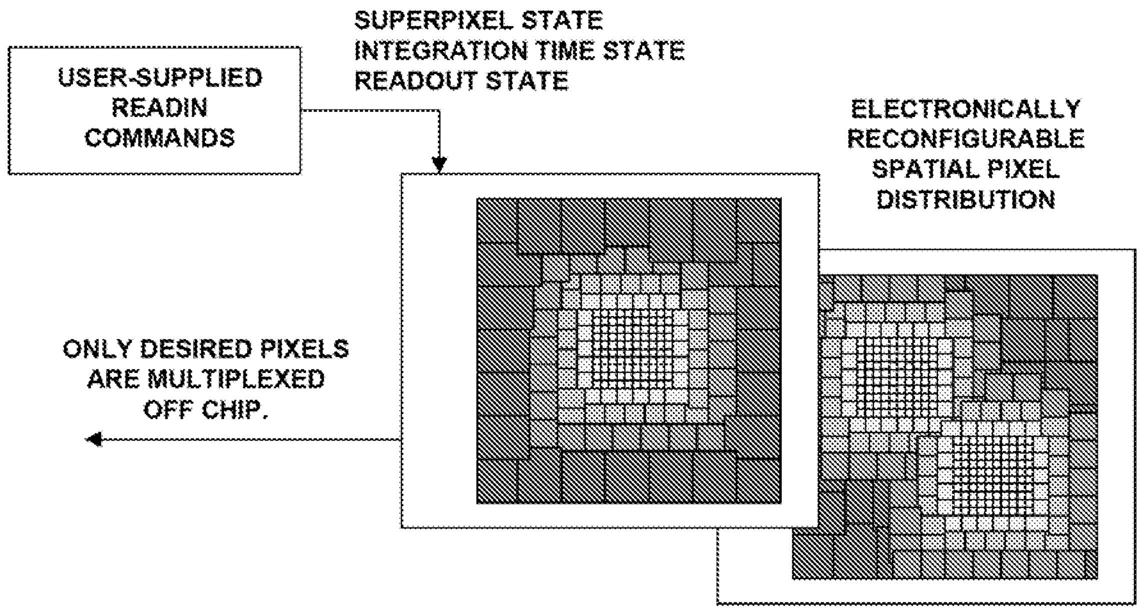

Figure 1. User-supplied commands are "read in" to each pixel, resulting in unique superpixel, integration time and readout state attributes.

¶ 7 As was previously designed and demonstrated in the "Neuromorphic Infrared Focal Plane Array", a DACIN word was multiplexed onto the FPA for each pixel in the FPA. In a similar manner, the READIN word multiplexed into each pixel of this Foveal FPA will be used in each pixel to set it's unique superpixel, integration time and readout state. Notice that ANY spatial configuration for the Foveal FPA would be possible; only two such configurations are shown in the figure. This capability would also permit a variety of spatial convolutions to be performed, opening up an entirely new area of advanced on-FPA image processing to the technical community.

¶ 8 The superpixel configuration of each pixel will be used to configure switch closures in a switched-capacitor network that interconnects neighboring pixels. In effect, the combined integration capacitance for a given superpixel will be the parallel capacitance of all connected unit cells. The combined photocharge accumulated on the effective integration capacitance will produce a voltage that represents the signal on this effective superpixel. The "integration time state" condition programmed into each pixel will be used to control an extension in time to the integration period, thus permitting individual gain conditions in the individual pixels of the superpixel. This will provide a means for producing superpixels which have increased sensitivity for a variety of applications.

¶ 9 In order to maintain a high frame rate, only one value per superpixel need be multiplexed off-chip. The "readout state" condition programmed into each pixel is used to control the output condition for any given pixel. In concept, as the row select signal ripples down a column of the device during the readout operation, only those pixels which have been previously programmed to produce their output signal will do so. Since the controlling processor has the knowledge of which pixel channels are producing valid data, spatial coordinates associated with each pixel value will be apriori knowledge. A display processor with this information and the superpixel grey level value would be able to reconstruct a display representing the appropriate spatial information in the scene.